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Genetic Resources, Breeding Objectives and Production Performances of Indigenous Small Ruminant Populations of Ethiopia: A Review

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ABSTRACT

Globally, small ruminants (SRs) greatly contribute in food and nutrition security. The SRs in Ethiopia are diverse due to the diversified agro-ecologies and greatly contributed to the international SRs gene pools. Ethiopian SRs were under subsistence production and there was no national commercialized production system of SRs because the production system was low-input (mixed crop-livestock, pastoral and agro-pastoral production systems) followed by low-output system, and were not effectively used to contribute in the national food and nutrition security. The review objectives were to provide a synthesized information on the national indigenous goat and sheep genetic resources (IGSGRs) available and their national geographical distributions, on the breeding objectives of IGSGRs, production performances of IGSGRs and on the nationally imported goat and sheep genetic resources and their national impacts. There are controversial numbers of breeds of the IGSGRs, however, there were two more exotic sheep imported (9) than exotic goats (7) used for the national crossbreeding programmes (NCBPs) to improve the national SRs productivity. However, the NCBPs of the SRs were not successful due to incompatibility of the genotypes with the farmers breeding objectives, management methods and the low input production systems due to poor institutional supports. The unsuccessful NCBPs of the SRs were also largely confirmed by the higher national average percentages of the indigenous goat (99.94%) and sheep (99.69%) reports of the national CSA reported in 2016 through 2022. At national level, breeding objective traits of Menz, Bonga, Horro, and Afar sheep breeds were clearly defined, however, production system based participatory *breeding objectives and associated selection traits* of each goat and sheep populations were not identified. Average age at first mating (AFM) of the reviewed indigenous goats was 7.87 months whilst their average age at first kidding was 14.63 months. AFM of the reviewed indigenous sheep was 8.61 months whilst their average age at first lambing was 15.01 months. Average parturition interval (PI) and litter size at birth (LSB) of the reviewed indigenous goats were 8.91 months and 1.40 whereas the average PI and LSB of the reviewed indigenous sheep were 8.81 months and 1.33, respectively. Average six-month weight (6MW) and yearling weight (YW) of the reviewed indigenous goats were 11.50 Kg and 17.41 Kg whereas the average 6MW and YW of the reviewed indigenous sheep were 16.16 Kg and 21.75 Kg, respectively. Average daily milk yield of the reviewed indigenous goats was 0.65 liter milked for about 3.41 months, however, the reviewed indigenous sheep were not milked except Begait sheep (0.47 liter/ewe/day). Overall, the growth, reproductive and productive performances of the IGSGRs were very poor, and quick genetic and management improvements should be made to enhance their productivity. Research on meat and mutton characteristics and quality aspects of the IGSGRs was ignored. Therefore, national research institutions should be involved in identifying the meat and mutton characteristics and quality parameters of the IGSGRs. Revised national genetic characterizations should be conducted to properly identify the IGSGRs and avoid the controversy in the national breed numbers of both species. Modern breeding and husbandry practices should be used to extensively exploit the diversity and huge populations of the IGSGRs. Genetic improvement and conservation of the IGSGRs should also be of first national priority.

Keywords: Age at first kidding; Age at first lambing; Carcass weight; Gene inflow; Geographical distribution; Kidding interval; Lactation; Lambing interval; Litter size at birth; Production system; Yearling weight.

1. Introduction

Meat, milk, skin, fiber, horn and offal as products and the by-products which comprise of manure as fertilizer, and dung as fuel and for biogas production are the benefits obtained from small ruminants (SRs). Moreover, they also provide indirect benefit (weed control), intangible benefits [1, 2]. SRs are also sources of foreign currency [3] which enhances national agricultural GDP. African sheep have been traditionally classified based on their tail type [4, 5] because the earliest sheep in Africa were hairy thin-tailed and introduced to East Africa, and the second wave of sheep introduction to Africa constitutes fat-tailed sheep entering North Africa via the Isthmus of Suez straits and East Africa via the straits of Bab-el-Mandeb [5]. Africa was the home of 89 breeds and types of goats and there were approximately 570 breeds and types of goats in the world [6].

Ethiopia has diversified topographic features with altitudes ranging from areas below sea level in the Danakil depression to extremes of 4,500 meter above sea level in the Semien mountains [7]. Ethiopia has a large farm

animal genetic resources diversity due in large part to its geographical location near the historical entry point of many livestock populations from Asia [8]. Moreover, Ethiopia is one of the biodiversity rich countries in the world due to its great geographic diversity, and macro- and micro-climatic variabilities. The country has ten ecosystems, and 18 major and 49 minor agro-ecological zones. Hence, Ethiopia is endowed with great diversity of plant, animal and microbial genetic resources [9]. Evolutionary forces of mutation, selective breeding, adaptation, isolation and genetic drift caused by human intervention along with the environmental influence has been the ability to create large number of local sheep breeds [10].

Majority of the sheep (40%) and goats (40%) are concentrated in pastoral and agro-pastoral areas [11]. Ethiopia is a home for at least nine breeds and fourteen traditional sheep populations [12], however, EBI [13] reported that there were nine genetically distinct breeds of sheep characterized through phenotypic and molecular methods. The 14 varied sheep population types categorized in to four major groups which comprised of sub-alpine short fat-tailed, highland long fat-tailed, lowland fat-rumped/tailed and lowland thin-tailed [14], and Solomon [15] reported that there were nine genetically known indigenous sheep breeds in Ethiopia.

FARM Africa [16] characterized the goats of Ethiopia and Eritrea in to four families of fourteen goat populations which were classified as Nubian family (Nubian and Barka), Rift valley family (Worre, Afar, Abergelle, Arsi-Bale and Woyto-Guji), Somali family (Hararghe Highland, Short-eared Somali and Long-eared Somali) and Small East African family (Central Highland, Western Highland, Western Lowland and Keffa). However, microsatellite marker characterizations of the indigenous goats revealed eight distinctively different breeds which comprised of Arsi-Bale, Gumuz, Keffa, Long-Ear Somali, Woyto-Guji, Abergelle, Afar and Highland Goats [17]. Moreover, Felata, Arab, Gumuz, Oromo and Agew were identified as independent goat genetic types. Felata, Arab and Gumuz goats are known for their adaptation in harsh environmental and climatic conditions of Benishangul-Gumuz Regional State, Ethiopia [18]. Following Tesfaye [17] genetic characterization work, genetic characterization report of Mekuriaw [19] revealed only seven distinctively different goat breeds of Ethiopia. The national crossbreds and pure exotic percentages of goats and sheep were insignificant. The percentages of indigenous goats (99.97%, 99.93%) and sheep (99.81%, 99.62%) of Ethiopia [20,21], respectively were encouraging for conservation and improvements of the national indigenous genetic resources.

Temperate goat breeds are genetically more productive as compared to Ethiopian indigenous goats [22]. Genetic improvement using within breed selection is a slow and tedious process and it was recommended to practice crossbreeding using fast growing temperate sire lines [23]. However, breed substitution and crossbreeding programmes involving temperate breeds are seldom successful due to incompatibility of the genotypes with the breeding objectives of the farmers and production systems [24]. The exotic breeds (Corriedale, Hampshire and Romney) of sheep were abandoned because they were not accepted by the farmers as the breeds did not meet farmers' phenotypic preferences for horns and tails [25].

The Livestock Master Plan (LMP) roadmap of Ethiopia was developed holding nine value chain components which comprised of live animals and red meat/milk (cattle, goats, sheep, camels), cattle feedlots, family dairy (cattle, goat, and camel), specialized dairy, family poultry, specialized poultry (broilers and layers), hides and skins (production

and health issues), animal feed, health and genetics and animal health [26]. The goat and sheep genetic resources of the country were included under three major economic value chains. However, LMP roadmap did not changed in to practice because some potential indigenous goats (Begait and Nubian) and sheep (Begait) were not also involved in to one or all of the economic value chains.

The total annual national meat production shares of cattle (63%), goats (12%) and sheep (25%) [27] where beef was the most important source of animal protein. However, the indigenous sheep populations of Ethiopia are generally characterized with low level of growth rate and carcass yield productivity [28], and a yearling goat in Ethiopia yielded a carcass weight of only 8.5 Kg [27,1]. Ethiopian goat production accounts for 16.8% of total meat supply and 16.7% of milk consumed [29]. Sheep have multipurpose functions because they provide meat, manure and serve as source of income [30]. Valued goat commodities (milk, meat and skin) are considerable potential commodities for improved goat production though there are severe environmental constraints to increase goat productivity [31]. Poor nutrition, genotype, inadequate indigenous breed utilizations for production, limited knowledge of the husbandry practices and environment were the major factors attributed to low productivity of the indigenous sheep [32].

The indigenous goats and sheep genetic resources (IGSGRs) of the country and their geographical distributions are well described (Table 2). Moreover, the imported goats and sheep genetic resources are also listed along with their purposes of importations and their national outcomes and impacts (Table 3). The indigenous small ruminants have multi-faced roles compared with the temperate populations. The information on the diversity, distribution, production performances and annual population growth rates of the IGSGRs will be nationally important to the ministry of agriculture and rural development (MoARD) and Regional and National Research Institutions (RNRIs), and the different stakeholders including Ethiopian biodiversity institute (EBI), national animal genetic improvement institute (NAGII), national artificial insemination center (NAIC) and the policy makers.

Identification and understanding of the distribution, breeding objective and productive performances of the IGSGRs will also be paramount important for the national breeding and production investment opportunities. The current demand of the public to small ruminant meat is highly increased, however, the indigenous small ruminants have slow growth rates and very low marketable body weights. Understanding the productive performances of the indigenous goat and sheep invites strategic interventions and modern production systems on the most productive population(s) of goat and/or sheep, and used to design appropriate breeding programmes.

1.1. Review Objectives

1-To provide a synthesized information on the national indigenous goat and sheep genetic resources (IGSGRs).

2-To provide a synthesized information on the national geographical distributions of the IGSGRs.

3-To provide a synthesized information on the breeding objectives of IGSGRs.

4-To provide a synthesized information on the production performances of IGSGRs.

5-To provide a synthesized information on the nationally imported goat and sheep genetic resources and their national productivity impacts.

2. Discussion of Findings

2.1. Small Ruminant Genetic Resources of Ethiopia

2.1.1. National Annual Population Growth Rates and Comparisons of Goats and Sheep Populations

The population of goats increased across years than sheep. There were peak national annual growth rates of goats (29.61%) and sheep (20.82%) in 2020. On the contrary, annual growth rates of the national goat population in 2017 (1.67%) and 2021 (3.88%) were extremely low due to different regional and national reasons (Figure 1). The average national growth rate of goats (12.52%) was higher than the average national growth rate of sheep (8.42%) in 2017 through 2021 (Table 1). The composition of genotypes of goat and sheep genetic resources were predominantly indigenous genotypes because there were averages of 99.94% of national indigenous goats and 99.69% of national indigenous sheep in the last seven years. The national proportions [33, 34, 20, 35, 36, 37, 21] of exotic and indigenous crossbreds and pure exotics of goat and sheep genetic resources were negligible (Table 1). National average proportion of 2016 through 2021 of exotic and indigenous crossbreds of sheep (**0.244%**) was the highest recorded and was not comparable with the national average proportion of exotic and indigenous crossbreds (**0.04%**) of goat of the same years (Table 1).

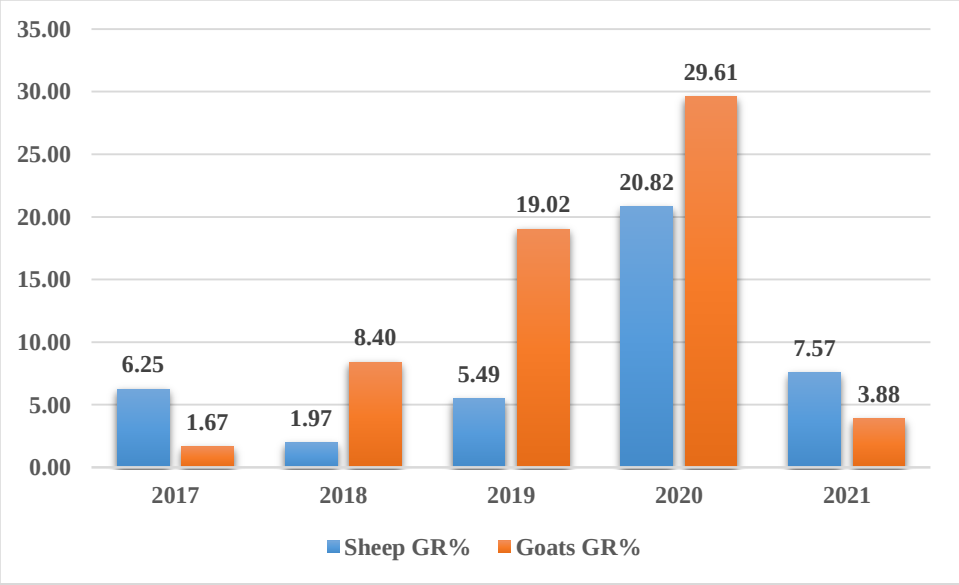

Figure 1. National Annual goats and sheep population growth rates (%) in 2017-2021

Table 1. National Annual Growth Rates of Goat and Sheep Populations in 2017-2021 (CSA)

Year	Goats		Sheep		% of indigenous genotypes		% of Crossbred and Exotic goat genotypes		% of Crossbred and Exotic sheep genotypes	
	Population (million heads)	Growth rate per annum (%)	Population (million heads)	Growth rate per annum (%)	Goats	Sheep	Crossbred	Exotic	Crossbred	Exotic
2016*	29.70	-	28.89	-	99.96	99.85	0.03	-	0.09	-
2017*	30.20	1.67	30.70	6.25	99.97	99.72	-	-	0.22	0.06

2018*	32.74	8.40	31.30	1.97	99.97	99.81	-	-	0.12	-
2019*	38.96	19.02	33.02	5.49	99.98	99.72	-	-	0.27	0.01
2020[SP]	50.50	29.61	39.89	20.82	99.88	99.56	0.06	-	0.28	-
2021[SP]	52.5	3.88	42.9	7.57	99.9	99.52	0.05	0.05	0.41	0.08
2022[SP**]	46.0	-	38.0	-	99.93	99.62	0.03	0.04	0.32	0.06
Average	40.1	12.52	34.96	8.42	99.94	99.69	0.04	0.04	0.244	0.05

Data Source: [33, 34, 20, 35, 36, 37, 21], CSA-Central Statistical Agency, * Rural Sedentary areas of the country, SP- It includes Sedentary and Pastoral areas, **the census excludes Tigray Region

Table 2. National Indigenous goats and sheep genetic resources and their geographical distributions

Indigenous goat genetic resources	Geographical distributions	Remark
Arsi-Bale [16, 17, 38]	Highlands of Bale, and Hararghe [39], Arsi, Bale, Sidamo and Western Hararghe Zones [8]	
Gumuz [17, 38, 18], Western Lowland goats [16]	Along the area bordering the Sudan [16, 40], Northwestern lowlands (Asossa, but also Metekel and Kamashi Zones) [8]	
Keffa [16, 17, 38]	Highlands and Lowlands of Keffa and South Shoa Zone [16, 40], Keffa and adjoining parts of Kembata and Hadiya [8]	
Woyto-Guji [16, 17, 38]	South Omo, Southern Sidama and Wolayita [8], North Omo, South Omo, Sidamo, Borana [8]	
Abergelle [16, 17, 38]	Along Tekeze river of Tigray region, Wag Himra, East Gondar [16, 40], Southern Tigray, North Wollo and South Gonder [8]	
Afar [16, 17, 38]	Afar region, Northern and Western Hararghe [16, 40], Afar Region and parts of Eritrea and Djibouti with the Afar pastoralists [8]	
Highland goats [17], Western Highland goats [16]	Central Highlands, west of the Rift Valley, Wollo, Gondar and Shoa [16]	
Eastern and Southeastern goats [17], Short and Long Eared Somali goats [16]	Eastern and Southeastern of Ethiopia [16]	
Barka [18], Begait [38, 31, 41]	West and South West Eritrean lowlands, and Western Tigray [42], Northern and North-western Ethiopia near the border with Eritrea and the Sudan [8], North Western Zone of Tigray, Ethiopia distributed in Tahtay Adiabo district [41]	Adult female weighed 33.8±5.3 Kg whilst adult male weighed 45.3±14.1 [16].
Nubian [42, 16, 18], Hassan [41]	Western Tigray and Eritrea [42], distributed in Lowlands of Western Eritrea (Gash and Setit) [16], Lowland areas of Western Zone of Tigray, Ethiopia [41]	Hassan goat is the local name of Nubian goat, and adult female weighed 34.1±5.4 Kg whilst adult male weighed 30.0±4.2 [16].

Arado [41]	Western Zone of Tigray, Ethiopia which are distributed in Tsegede, Welkait districts, and highland Kebelles of Kafta Humera [41]	
Felata [38, 18, 31]	North-western lowlands (Asossa), but also Metema [8], Arid and semi-arid zones of Benishangul-Gumuz Regional State, Ethiopia [43]	
Arab [38, 18, 31]	North-western lowlands (Asosa) [8], Arid and semi-arid zones of Benishangul-Gumuz Regional State, Ethiopia [43]	
Oromo [38, 18, 31]	North-western highlands (Asosa) [8], In Benishangul-Gumuz Regional State which are borders to Oromo Regional state, Ethiopia [43]	
Ille [38, 31]	Found in Tigray Regional State [38]	
Maefur [38, 44]	Erob district of Eastern Zone Tigray [44]	Adult body weight: male-34.7 Kg and Female-28.9 Kg [44]
Borana goats [45]	in Yabello district of Borana Zone, Oromia Regional State, Ethiopia [45]	
Central Abergelle [46]	South North Wollo [46]	
Agew [18, 46]	Agew-Awi [46]	
Begia-Medir [46]	South Gonder-West Gojam [46]	
Bati [46]	Oromia [46]	
Menz [47, 48, 49, 38, 50, 14]	Highlands of Northern and Central Shoa and some parts of Wollo [8]	
Tukur [47, 48, 49, 38, 50, 14, 51]	Highlands of Northern Ethiopia (parts of Tigray, Gondar and Wollo) [8, 14], in the highlands of the North Wollo Zone; the breed adapted to sub-alpine cool highland weather conditions [51]	
Wollo [47, 48, 49, 50, 14]	South Wollo Zone of Amhara Regional State [14]	
Horro [47, 48, 49, 38, 50, 14]	Highlands of Western Ethiopia (West Shoa, Wellega, Kaffa and Illubabor) [8]	
Arsi Bale [47, 48, 49, 14, 38, 50]	Highlands of Eastern and South Central Ethiopia (Arsi, Bale, Hararghe, Sidamo and South Shoa) [8]	
Blackhead Somali [47, 38, 48, 49, 50, 14]	Rangelands of Eastern, South-eastern, Southern and South-western Ethiopia [8]	
Adal or Afar [47, 48, 49, 38, 50, 14]	Afar Region and parts of Dire Dawa and South Wollo with the Afar Pastoralists [8]	Afar sheep is also known as Elle sheep [52], and is a breed adapted to drought prone arid and semi-arid areas of Afar Region.
Simien [47, 48, 49, 50, 14]	North Gondar zone of Amhara Regional State (Debark, Dabat, Janamora, Wegera) [14]	

Farta [47, 48, 49, 38, 50, 14]	Sub-moist highland at altitude of 2000-2500 meter above sea level in South Gondar zone; Gondar zuria, Belesa and Dembia Districts [12, 38]	
Gumuz/Shankila [47, 48, 49, 50, 14]	Benishangul-Gumz Regional state; lowlands of North Gondar [14]	
Washera/Dangila/Agew [47, 48, 38, 49, 50, 14]	West and East Gojam and Agew Awi zones of Amhara Regional state; Dangur, Madura and Alefa Takusa districts [14]	
Sekota-Agew [47, 48; 49, 50, 14]	Wag Himra zone of Amhara Regional State and Tigray Regional State [14]	
Bonga [47, 48, 49, 38, 50, 14]	Keffa, Sheka and Bench zones of Southern Regional State [14]	
Begait [38, 50, 53, 52, 54]	Western Zone of Tigray, Ethiopia [54], in Western and North Western Tigrai including districts such as Tahtay–Adyabo, lowlands Tsegede, and Kafta Humera [53, 52]	
Arado or Common Tigray Highland sheep [55, 52, 54]	in all mid and highlands of Tigray Region [55, 52, 54]	
Abergelle [38, 52]	in Tigray Regional State [38], in Tanqua-Abergelle, Tselemti, Kola Temeben and Alamata, lowlands of Ofla and Sokota [53], Tanqua-Abergelle and neighboring woredas of Amhara Region [52]	
Ille [38, 52]	in Tigray Regional State [38], in Raya-Azebo district and Afar region [53], Southern Tigray and commonly in Afar Region [52]	

Not Available (NA)

Table 3. Imported breeds of goat and sheep genetic resources and their national outcomes and impacts

Imported goat breeds	Purpose of importation	Outcome	Impact
Saanen [56, 57, 58]	To improve milk production [57]	Ethiopian highland goats and Saanen of half-bred does indicated a substantial increase in milk production (19 to 52 kg) in (a 12-week lactation) [59]	No impact [56] The crossbreds were not productive under village goat production conditions [60].
Anglo Nubian [61, 38; 56, 57, 58]	To improve the milk yield of the local breeds through crossing with exotic Anglo-Nubian goats [61, 38, 57]	Anglo-Nubian and Somali crossbred goats (837 ml) was higher than pure Somali (330 ml) goats [16]	No impact [56] The crossbreds were not productive under village goat production conditions [60].
Toggenburg [38, 56, 57, 58]	To improve milk yield [38, 57, 62]	Toggenburg x Arsi-Bale crossbred (0.93 liter) produced lower milk yield than Arsi-Bale (1.13) does [62]	No impact [56] The crossbreds were not productive under village goat production conditions [60].

Boer [38, 56, 57, 58]	To improve meat production of local goats [38].	Lower growth rates of Boer and their crossbreds than local goats [63], Boer-Abergelle F1 kids exhibited high growth rates (range 73 to 113 g/day) [64], higher milk yield in Boer x Central Highland (BxCH) goats than Central highland [65], higher birth weight and weaning weight of BxCH crossbred kids than CH [66]	No impact [56] The crossbreds were not productive under village goat production conditions [60].
Damascus or Shami [67]	To improve milk production [68]	NA	NA
Beetal [68]	To improve milk production [68]	NA	NA
Jamnapari [68]	To improve milk production [68]	NA	NA
Bleu du Maine [38, 56]	NA	NA	No impact [56]
Merino [38, 56, 69]	NA	NA	No impact [56]
Rambouillet [56, 70]	To produce and supply finer and longer wool fiber [69, 71]	Good growth and wool production performance under on-station and on-farm conditions [23]	No impact [56]
Romney [38, 56, 70]	To produce and supply finer and longer wool fiber [69, 71]	Good growth and wool production performance under on-station and on-farm conditions [23]	No impact because the breed was not accepted by the farmers as the breed did not meet farmers' phenotypic preferences [56, 25]. But Getachew *et al*. [23] reported Romney was accepted by the farmers.
Hampshire [38, 56, 70]	To produce and supply finer and longer wool fiber [69, 71]	Good growth and wool production performance under on-station and on-farm conditions [23]	No impact because the breed was not accepted by the farmers as the breed did not meet farmers' phenotypic preferences [56, 25].
Corriedale [38, 56, 70]	To produce and supply finer and longer wool fiber [69, 71]	Good growth and wool production performance under on-station and on-farm conditions [23]	No impact because the breed was not accepted by the farmers as the breed did not meet farmers' phenotypic preferences [56, 25].
Dorper [38, 56, 70, 72, 23, 73]	To improve productivity of the local sheep through crossing [72], to utilize the fast growth rate and large carcass of the breed [23], to improve the	Crossbreds often outperformed in body weight compared to their local Contemporaries [74], crossbred sheep performed significantly better than local sheep, and crossbred sheep exhibited meat type traits [75]	No impact [56]

	growth performance of lambs [74].		
Awassi [38, 56, 71, 70; 23], Awassi breed was imported from Israel, to cross with the indigenous Menz [76]	To improve wool and meat production [77, 78], to improve the growth performance of lambs [74]	Crossbreds often outperformed in body weight compared to their local Contemporaries [74]	No impact [56], however, likely to dilute the indigenous Menz sheep breed [79] and the genetic diversity of Tikur sheep threatened due to indiscriminate cross-breeding with Awassi sheep [78]
Rutanna [80, 81, 54]	Mutton production [54]	Fast growth rate and big body size [81, 54], Community livelihood changes due to mass sale of Rutanna to Sudan (illegal cross-border trade) [54]	Complete breed substitution: Rutanna substituted Begait sheep in some Kebelles of Kafta Humera [54].

Not Available (NA)

2.2. Breeding Objectives and Selection

Breeding objective is a direction in which farmers determine their demand for specific products and services from the animals and increasing profit [82]. Breeding objectives include all relevant characteristics of an animal such as production, reproduction, fitness, and health characteristics [24]. Breeding objective traits have to be easy to measure, heritable and variable, and not too many [83]. Selection of traits that enhance goat and sheep ability to survive and thrive in the local environment are major breeding objectives. The selection of traits such as disease resistance, heat tolerance, and good foraging ability [84] could enhance survival. The second important breeding objective for sheep and goats in Ethiopia is to select traits that increase the productivity of goat and sheep. The selection of traits could include increased milk yield, increased growth rate, and improved reproductive performance and to maximize the profits of goat and sheep [85, 86].

The four methods used to define breeding objective traits include semi-structured questionnaire, choice card experimentation, group discussion and ranking of live animals [87, 88, 89]. Moreover, identification of breeding objectives of goats in Ethiopia have been used various methodological approaches which comprised of choice experiment method, ranking among a list of traits, and live animal rankings [90]. *One needs to start with defining the breeding objective in selecting the most desirable breed or breed combination and selecting within a breed* [24]. Gizaw *et al*. [91] work is a good exemplary breeding objective traits identification in Menz, Bonga, Horro and Afar sheep populations. Cash income generation was the first production objective of sheep rearing and meat production as a second and capital investment was the third [70].

Many crossbreeding programs of small ruminants in tropical countries were not successful because of the incompatibility of the genotype with the farmers breeding objectives, management methods and the prevailing environment of the tropical low input production systems [92]. Small ruminants in Ethiopia are mainly kept for income generation in many parts of the country to obtain cash income for household expenses [93]. The reasons of keeping animals are the breeding objectives of the animals. However, the breeding objectives of some indigenous

goat and sheep genetic resources of Ethiopia were identified (Table 4), and breeder attention is highly needed in identifying the breeding objectives of the remaining genotypes of goats and sheep of the country to boost their productivity.

Table 4. Breeding/Production Objectives of indigenous goat and sheep genetic resources

Goat/sheep	Breed	Production system	Breeding objectives			Source(s)
			First Rank	Second Rank	Third Rank	
Sheep	Bonga	Not specified	Mutton production	NA	NA	[94]
Sheep	Horro	Not specified	Mutton production	NA	NA	[94]
Sheep	Menz	Not specified	Coarse wool and mutton production	NA	NA	[94]
Sheep	Bonga	Extensive system	Cash income	Meat	Saving	[95]
Sheep	Horro	Extensive system	Cash income	Meat	Saving	[95]
Sheep	Begait	Extensive system	Cash income	Meat	Manure	[53]
Sheep	Begait	Extensive system	Meat production	Cash income	Consumption	[96]
Goat	Hararghe highland	Extensive system	Meat production	NA	NA	[97]
Goat	Highland	Extensive system	Cash income	NA	NA	[98]
Goat	Abergelle	Extensive system	Cash income	NA	NA	[98]
Goat	Arab	Extensive system	Cash income	Meat	Saving	[99]
Goat	Oromo	Extensive system	Cash income	Meat	Saving	[99]
Goat	Abergelle	Extensive system	Meat production	NA	NA	[64]
Goat and sheep	Afar goats and sheep	Pastoral Production System	Home milk consumption	Live animal saving	NA	[100]
Goat and sheep	Afar goats and sheep	Agro-Pastoral Production System	Cash income	Home milk consumption	NA	[100]
Sheep	Horro	Extensive system	Mutton production	NA	NA	[101]
Sheep	Sheep	Extensive system	Cash income	Mutton production	Manure production	[102]

Sheep	Sheep	Extensive system	Cash income	Saving	Mutton production	[103
Sheep	Sheep	Extensive system	Cash income	Mutton production	Saving	[104]
Sheep	Afar	Agro-pastoral production	Cash income	Milk production	Mutton production	[105]
Sheep	Afar	Pastoral production	Cash income	Milk production	Saving	[105]
Sheep	Afar	Agro-pastoral and pastoral productions	Mutton production	NA	NA	[106, 107]
Sheep	Arado/Common Tigray Highland	On-farm (Non CBBP and CBBP)	Cash income	Mutton production	Saving	[108]
Sheep	Tikur	Extensive system	Cash income	Saving	Prestige	[109]
Sheep	Sheep	Extensive system	Cash income	Mutton production	Saving	[110]
Sheep	Bonga	Extensive system	Cash income	Saving	Mutton production	[111]

Not Available (NA)

2.3. Reproductive and Dairy Performances of indigenous goat and sheep

Performance evaluation, phenotypic and DNA molecular characterizations enable breed characterization [112]. Age at puberty, age at first lambing/kidding, post-partum interval, parturition interval and fertility indices are measures of reproduction commonly used in sheep and goats [57, 89]. The low productivity of sheep and goats are characterized by growth rates, meat and milk production [47]. The indigenous Ethiopian goats exhibited a litter size at birth (LSB) of between 1.07 and 1.5. The LSB is largely determined by ovulation rate [113].

The reproductive performances of some indigenous goat and sheep genetic resources kept under different management options are presented (Tables 5 and 6). The shortest age at first mating (AFM) of the indigenous goats was 6.58 months (Hassan or Nubian goats kept at extensive production system) whilst the longest AFM was 9.3 months (Bonga goats kept at extensive production system). The shortest age at first kidding (AFK) of the indigenous goats was 11.95 months (Arsi-Bale goats kept at extensive production system) whilst the longest AFK was 28.5 months (Arsi-Bale goats kept at intensive production system) (Table 5). The shortest age at first mating (AFM) of the indigenous sheep was 5.7 months (Begait sheep kept at extensive production system) whilst the longest AFM was 17.97 months (Blackhead Somali sheep kept at extensive production system). The shortest age at first lambing (AFL) of the indigenous sheep was 9.19 months (Adilo sheep kept at extensive production system) whilst the longest AFL was 24.8 months (Menz sheep kept at extensive production system) (Table 6).

Goat milk is richer in vitamins and minerals compared to cow milk, particularly appropriate in the diet of the elders, the sick and children [114, 115]. Goat milking was practiced, and the lower daily milk yield (DMY) and higher DMY of the indigenous goats were 0.28 liter (Central Highland goats kept at semi-intensive system) and 1.13 liter

(Arsi-Bale goats kept at semi-intensive system) (Table 7). However, sheep milking was not practiced except Begait sheep (0.47 liter per ewe per day in the wet season) (Table 7). Jemberu *et al*. [116] also reported that milk from small ruminants was underutilized.

Table 5. Mean Reproductive Performances (months) of indigenous goats

Breed	Production system	AFM	AFK	KI	LSB	Source
Begait	Extensive system	7.79	13.15	-	1.29	[41]
Hassan	Extensive system	6.58	12.45	-	1.33	[41]
Arado	Extensive system	7.68	14.56	-	1.27	[41]
Abergelle (3 year)	Semi-extensive system	-	-	11.3	1.08	[64]
Central highland	Semi-extensive system	-	-	-	1.58	[65]
Woyto-Guji	Extensive system	-	-	5.47	-	[117]
Central highland	Extensive system	-	-	6.6	-	[117]
Abergelle	Extensive system	-	14.9	11.3	1.04	[118]
Arsi-Bale	Intensive system	-	28.5	9.8	1.64	[119]
Arsi-Bale	Intensive system	-	19.2	9.3	1.60	[120]
Abergelle	Extensive system	-	-	12.1	1.03	[121]
Central highland	Extensive system	-	-	8.9	1.40	[121]
Woyto-Guji	Extensive system	-	-	10.3	1.09	[121]
Woyto-Guji	Extensive system	-	-	-	1.13	[122]
Arab	Extensive system	8.54	13.65	8.52	1.58	[43]
Felata	Extensive system	7.75	12.90	7.85	1.73	[43]
Gumuz	Extensive system	7.48	12.54	7.67	1.91	[43]
Bonga	Extensive system	9.3	14.9	8.9	-	[95]
Horro	Extensive system	7.8	13.3	7.8	-	[95]
Keffa	Extensive system	-	12.5	7.9	1.70	[123]
Arsi-Bale	Extensive system	-	12.1	6.9	1.75	[124]
Adilo	Extensive system	-	12.9	-	1.24	[115]
Arsi-Bale	On-station	-	-	11.6	1.34	[125]
Arsi-Bale	Extensive system	-	-	8.1	1.21	[126]
Arsi Bale	Extensive system	-	11.95	9.05	1.47	[127]

Age at First Mating (AFM), Age at First Kidding (AFK), Kidding Interval (KI), Litter Size at Birth (LSB).

Table 6. Mean Reproductive Performances (months) of indigenous sheep

Breed	Production system	AFM	AFL	LI	LSB	Source
Afar	Not specified	-	-	-	1.03	[128]
Gumuz	Not specified	-	-	-	1.47	[128]
Begait	Not specified	-	-	-	1.26	[128]
Tukur	Extensive system	9.09	14.1	8.35	-	[129]
Wollo	Extensive system	10.4	15.5	8.01	-	[129]
Tumele	Extensive system	8.20	13.1	8.73	-	[129]
Farta	Extensive system	-	15.7	9.3	1.1	[129]
Begait	Extensive system	5.7	11.34	6.79	1.33	[130]
Washera	Extensive system	-	13.3	9.8	1.11	[131]
Farta	Extensive system	-	13.7	9.5	1.01	[131]
Menz	Extensive system	-	24.8	8.9	1.43	[132]
BHS	Extensive system	17.97	23.56	10.46	-	[133]
Begait	Extensive system	7.15	12.88	-	1.29	[134]
Arado/Common Tigray Highland	Extensive system	8.61	14.93	-	1.05	[134]
Abera	Extensive system	-	12.9	9.6	1.9	[135]
Adilo	Extensive system	-	9.19	12.43	1.5	[136]
Arsi-Bale	Extensive system	-	12.7	7.8	1.7	[124]
BH Ogaden	Extensive system	-	23.56	10.63	-	[133]
Gumuz	Extensive system	-	13.67	6.64	1.17	[137]
Washera	Extensive system	-	15.5	9.04	1.11	[138]
Abera	On-station	-	-	-	1.12	[139]
Abera	On-farm	-	-	-	1.34	[139]
BHS	On-station	-	22.22	10.53	-	[140]
Bonga	Extensive system	8.4	14.9	7.8	1.4	[95]
Horro	Extensive system	7.5	13.3	8.9	1.6	[95]
Washera	Extensive system	6.6	11.5	9.0	1.3	[141]
BHS	Extensive system	6.5	12.7	6.6	-	[142]
	Agro-pastoral	6.7	13.8	8.8	-	[142]
	Pastoral	9.1	14.7	10.2	-	[142]
Menz	Extensive system	-	15.7	8.5	-	[143]
Afar	Extensive system	-	13.5	9.0	-	[143]
Bonga	Extensive system	7.5	12.81	7.52	1.5	[103]
Arado/Common Tigray Highland	Extensive system	10.85	18.15	9.6	-	[144]

Elle	Extensive system	7.42	16.83	7.6	-	[144]
Arado/Common Tigray Highland	On-farm (CBBP)	-	16.4	8.5	1.16	[108]
Arado/Common Tigray Highland	On-farm not CBBP	-	16.6	8.6	1.07	[108]
Bonga	Extensive system	-	13.0	8.0	-	[123]
Adilo	Extensive system	-	14.6	-	1.42	[115]
Arsi Bale	Extensive system	-	12.43	9.19	1.52	[127]

Age at First Mating (AFM), Age at First Lambing (AFL), Lambing Interval (LI), Litter Size at Birth (LSB), Blackhead Somali (BHS) sheep.

Table 7. Mean Milk Yield Performances of Indigenous Goats and Sheep Populations

Breed	**Production system**	**Lactation performance**		**Source**
		DMY (liter)	**LL (months)**	
Milk Yield Performances of Indigenous Goats				
Begait	Extensive system	0.67a	1.77a	[41]
Hassan	Extensive system	0.70a	1.79a	[41]
Arado	Extensive system	0.38a	0.75a	[41]
Central highland	Semi-intensive system	0.28	3.4	[65]
Arsi-Bale	Semi-intensive system	1.13	-	[62]
Somali	Semi-intensive system	0.85	-	[62]
Arab	Extensive system	0.52	-	[43]
Felata	Extensive system	0.61	-	[43]
Gumuz	Extensive system	0.59	-	[43]
Begait	Extensive system	0.75	-	[145]
Abergelle	Extensive system	**0.32**	-	[145]
Abergelle	On-station	0.39	2.1	[146]
Begait	Extensive system	0.47a	1.85	[134]

Daily Milk Yield (DMY), Lactation Length (LL), Wet season lactation (a).

2.4. Growth and Carcass Performances of indigenous goat and sheep

The small ruminant national annual meat production is relatively small compared to their national populations [93]. The dressing percentages of the indigenous sheep (42.5%) [147] and goats (42-45%) were very low due to poor nutrition and husbandry practices which exacerbated by the effects of drought [148]. The carcass weight (8.5 kg) produced from yearling goat in Ethiopia is low [27, 1]. The global average meat consumption per capita per year (38

kg) and the average meat consumption per capita per year of USA (124 kg) [29] are not comparable with the average annual per capita meat consumption of Ethiopia (8 kg). The sheep and goats contributed 77 and 62 thousand metric tons from mutton and goat meat production, respectively [29]. The average carcass weight of Ethiopian goats (10 kg) is the second lowest in sub-Saharan (SS) Africa [1]. The national sheep productivity is also generally extremely low. The average carcass weight per slaughtered sheep was 10 Kg with annual off-take rate of 32.5% for the years 2000 to 2007 [2] which is the lowest carcass yield among the SS countries. The offtake rate of Arsi-Bale goats (30.37%) was lower than the offtake rate of Arsi-Bale sheep (41.8%) in Alaba Special Woreda, Southern Ethiopia [127] which indicated the communities of the area preferred mutton to goat meat. However, a national report indicated that about 80% of meat exported to the Middle East was goat meat [149].

The growth and carcass performances of some indigenous goat and sheep genetic resources kept under different management options are presented (Table 8). Indigenous goats with larger six-month weight (6MW) was Highland goat kept at extensive production system (17.53 Kg) whilst indigenous sheep breed with larger 6MW was Washera sheep (22.7 Kg). Lowest and highest yearling weights (YW) of the indigenous goats were 13.74 Kg (Abergelle goats kept at on-station condition) and 24.2 Kg (Gumuz goats kept at extensive production system) (Table 8) whereas the lowest and highest YW of the indigenous sheep were 17.1 Kg (Horro sheep kept at extensive production system) and 28.8 Kg (Abera sheep kept at on-farm system) (Table 8). Carcass characteristics (hot carcass yield and dressing percentage) were not reported in 28 reports of indigenous goats (Table 8), and except in Menz, Horro, Rutanna, Gumuz and Washera sheep, there was no carcass characteristics report on indigenous sheep (Table 8).

Table 8. Mean growth and carcass performances of indigenous goat and Sheep Populations

Breed	Production system	Weight (Kg)		Carcass weight		Source
		6MW	YW	HCY (Kg)	DP (%)	
Growth and carcass performances of indigenous goat						
Abergelle	Extensive system	7.44	-	-	-	[121]
Central highland	Extensive system	10.96	-	-	-	[121]
Woyto-Guji	Extensive system	9.38	-	-	-	[121]
Woyto-Guji	Extensive system	13.3	18.9	-	-	[122]
Woyto-Guji	Extensive system	10.97	18.7	-	-	[43]
Begait	Extensive system	15.8	-	-	-	[145]
Abergelle	Extensive system	11.8	-	-	-	[145]
Gumuz	Extensive system	15.8	24.2	-	-	[80]
Borana goats	Semi-intensive system	14.12	21.86	-	-	[45]
Maale goats	Extensive system	10.97	18.72	-	-	[150]
Abergelle	Extensive system	11.08	-	-	-	[98]
Highland goats	Extensive system	17.53	-	-	-	[98]
Centeral Highland	Extensive system	10.6	-	-	-	[151]

Arsi-Bale	On-station	9.0	14.32	-	-	[152]
Arsi-Bale	On-station	9.0	14.31	-	-	[119]
Abergelle	Extensive system	9.13	14.25	-	-	[153]
Abergelle	On-station	8.55	13.74	-	-	[146]
Farta	Extensive system	13.89	20.35	-	-	[154]
Washera	Extensive system	16.1	23.5	-	-	[155]
Menz	Extensive system	13.1	20.1	8.2	38.6	[132]
Horro	On-farm (CBBP)	18.92	-	-	-	[156]
Horro	On-station	14.00	-	-	-	[156]
Washera	Not specified	22.7	-	-	-	[157]
Horro	Not specified	18-22	-	-	-	[157]
Bonga	Not specified	18-30	-	-	-	[157]
Afar	Not specified	19	-	-	-	[157]
Abera	On-station	18.21	25.08	-	-	[139]
Abera	On-farm	20.30	28.80	-	-	[139]
Washera	Extensive system	15.4	23.6	-	-	[138]
Menz	On-station	11.45	19.12	14.2	49.1	[158]
Horro	On-station	11.61	19.70	14.8	48.0	[158]
Abera	On-farm (CBBP)	20.8	27.9	-	-	[159]
Gumuz	On-farm	15.77	24.17	-	-	[80]
Arado/Common Tigray Highland	On-farm (CBBP)	13.76	18.91	-	-	[108]
Arado/Common Tigray Highland	On-farm not CBBP	13.53	18.57	-	-	[108]
Rutanna	On-station feeding trial	-	-	11.9	54.7 (EBW)	[160]
Gumuz	On-station feeding trial	-	-	10.1	50.9 (EBW)	[160]
Washera	On-station feeding trial	-	-	9.4	48.1 (EBW)	[160]

Six Month Weight (6MW), Yearling Weight (YW), Hot Carcass Yield (HCY), Dressing Percentage (DP), DP based on Empty Body Weight (EBW), Community-Based Breeding Programme (CBBP).

3. Conclusion

The indigenous small ruminants (goat and sheep) of Ethiopia are sources of the many tangible and intangible benefits mainly to the resource-poor-farmers, pastoralists and agro-pastoralists which contribute in their social, cultural and economic issues. There are diversified and populous goat and sheep genetic resources in the country, however, the contribution to the national economy is below the potential of the existing diversity and populations of the genetic resources due to many independent and interactive factors including lack of structured breeding and genetic improvement, feed scarcity, diseases and parasites prevalence, poor management practice and recurrent drought.

Age at first parturition (AFP), parturition interval (PI) and litter size at birth (LSB) of the reviewed indigenous goats were 11.95-28.5 months, 5.47-12.1 months and 1.03-1.91 whilst AFP, PI and LSB of the reviewed indigenous sheep were 9.19-24.8 months, 6.6-12.43 months and 1.01-1.9, respectively. Moreover, six-month weight (6MW) and yearling weight (YW) of the reviewed indigenous goats were 7.44-17.53 Kg and 13.74-24.2 Kg whereas the 6MW and YW of the reviewed indigenous sheep were 11.45-22.7 Kg and 17.1-28.8 Kg, respectively. Goat milking is almost common for child nutrition, however, the daily milk yield per doe was very low (0.65 liters). But national sheep milking was untapped practice. There were two more exotic sheep imported (Bleu du Maine, Merino, Rambouillet, Romney, Hampshire, Corriedale, Dorper, Awassi and Rutanna) than exotic goats (Saanen, Anglo Nubian, Toggenburg, Boer, Damascus or Shami, Beetal and Jamnapari), however, the exotic small ruminants did not exhibit national impact on productivity. The following future suggestions are forwarded to improve the national small ruminant productivity.

1-Research and development collaboration on indigenous goat and sheep genetic resources (IGSGRs) should be highly valued among MoARD, Regional and National Research Institutions (RNRIs), Ethiopian biodiversity institute (EBI), national animal genetic improvement institute (NAGII) and national artificial insemination center (NAIC) to improve genetic and productivity. Effective linkage and communication of the national institutions will be essentially important to improve productivity of IGSGRs.

2-Farmers experience sharing and capacity building on livestock breeding and production extension system should be the first priority of the Ethiopian government. The national livestock breeding extension system in general and indigenous small ruminant breeding extension system in particular should be led by the most recent breeding approaches, for example, community-based breeding programme (CBBP) is one best and most recent breeding and genetic improvement approach designed based on holistic production system analysis and participatory packages which could specifically avoid negative selection and enhance genetics and productivity of the small ruminants.

3-Exotic small ruminant genotypes and their crosses were not properly used because the national crossbreeding programme (NCBP) was very poor. There was no national impact on productivity of the imported small ruminants and their crossbreds except Awassi and Rutanna sheep resulted breed dilution and substitution, respectively. Therefore, in-depth focus and planned small ruminant (exotic and indigenous) NCBP should be implemented to enhance the productivity of the exotic small ruminant and their crossbreds.

4-The growth, reproductive and productive performances of the indigenous goats and sheep of the country were very poor. Hence, genetic and management system improvements should be made to enhance their productivity. Moreover, critical attention should be given to small ruminant milk and milking to contribute in the national food and nutrition security.

5-Meat and mutton characteristics and quality information of the small ruminants were not properly characterized, and should be one of the focus areas of the national research institutions.

6-There is phenotypic information of all the small ruminants in the country which did not appropriately distinguish the populations at national level. Therefore, revised national level genetic characterizations of the small ruminants

should be done to properly distinguish the diversity and breeds of the genetic resources. The controversy in the numbers of the breeds could be solved by this revised genetic characterization of the IGSGRs.

7-Simulation of alternative breeding schemes (breeding objective options) and breeding structures (pyramidal breeding) of **structured and selective breeding for genetic improvement and conservation** should be analyzed and practiced in selected potential IGSGRs to enhance their productivity. Selective breeding and genetic improvement needs a long-term investment, however, selective breeding enhances growth rate and other production performances of the IGSGRs.

8-Developing countries including Ethiopia have currently high demand on meat and mutton from the small ruminants. Hence, the vast marginal lands of the country should be extensively used for small ruminant breeding and production to enhance the current national small ruminant meat and mutton supplies. The government should motivate investors and cooperatives to the marginal land small ruminant breeding and production. Marginal land small ruminant breeding and production will not be adequately addressing the challenge but also should include forage development and production and modern production system.

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